Condition Assessment Manual

Appendix 1.05 – Guide for Draft Tube Gates Condition Assessment

Revision 1.0, 12/20/2011

Prepared by

MESA ASSOCIATES, INC.
Chattanooga, TN 37402

and

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6283
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

Contents

1.0 General

The primary purpose of draft tube gates is to protect the interior equipment and power generation components such as turbines by providing a barrier and blocking water flow during dewatering and unit shut down for maintenance and inspection activities. Since draft tube gates spend the majority of their life cycle in storage or moist conditions, they are likely to experience several maintenance and reliability issues such as:

- Corroded, bent, or damaged structural gate members and gate parts.
- Debris jamming gates
- Seal deterioration
- Misalignment of gate slots
- Concrete support deterioration, damage, or concrete growth
- Failure of crane and lifting parts

Gate replacement or gate slot repair can be very costly. Therefore, routine maintenance and condition assessments are very important in extending the life expectancy of gates and associated parts. By performing condition assessments, plants can estimate the remaining part life expectancy, identify any potential failure risks, and evaluate the benefits of part upgrade.

For draft tube gate systems, the three following steps are necessary to establish a condition indicator:

1) What parts are to be included in the condition assessment and what is their level of importance (parts and their weighting factors)?

2) What metrics/parameters are to be investigated for the quantitative condition assessment and what is their level of importance (condition parameters and their weighting units)?

3) How to assign numerical scores to the parts (rating criteria)?

This Appendix provides a guide to help answer the questions above, which can be applied to draft tube gates. The condition assessment is to be performed on a single gate system since even identical gate systems may have experienced different Operation & Maintenance (O&M) histories and would receive different value for condition indicators. Due to the uniqueness of each gate system (i.e. gate configuration, supports/slots, seals, etc.), the guides provided in this Appendix cannot quantify all factors that affect individual gate condition. Mitigating factors not included in this Guide may trigger testing and further evaluation to determine the final score of the draft tube gate condition and to make the decision of replacement or rehabilitation.

This Appendix is not intended to define draft tube gate maintenance practices or describe in detail inspections, tests, or measurements. Utility-specific maintenance policies and procedures must be consulted for such information.

2.0 Constituent Parts Analysis

For draft tube gates, the constituent parts are analyzed and listed in Table 1 (references to HAP Taxonomy).

If any part does not exist in a particular gate configuration, this part will be excluded from scoring mechanism by inputting “NA” into the Table. The effect of one part exclusion is usually insignificant to the entire system assessment and does not justify an adjustment of the weighting factors for the other parts.

3.0 Metrics for Condition Assessment

As listed in Table 1, the following five condition parameters are considered for the assessment of draft tube gates:

- The Physical Condition
- The Age
- The Installed Technology Level
- The Operating Restrictions
- The Maintenance Requirement

These five condition parameters are scored based on previous testing and measurements, historical Operation and Maintenance (O&M) records, original design drawings, previous rehabilitation feasibility study reports if available, interviews with plant personnel, and inspections where possible.

It can be noted that there is a certain level of relevance between the age and physical condition, maintenance needs, or some operating restrictions. However, as a benchmark condition assessment (without specific testing and measurements conducted on site) these five parameters are regarded as providing the basis for assessing the condition of draft tube gates.

In addition, the Data Quality Indicator, as an independent metric, is intended to reflect the quality of the available information and the confidence of the information used for the condition assessment. In some cases, data may be missing, out-of-date, or of questionable integrity. Any of these situations could affect the results of the condition assessment. The scores of data quality are determined by the on-site evaluators for each assessed part to indicate the data availability, integrity, and accuracy; and the confidence of the given condition ratings (MWH 2010).

4.0 Weighting Factors

There are two categories of weighting factors in Table 1. It is recognized that some condition parameters affect the condition to a greater degree than other parameters. Also, some parts are more or less important than other parts to the entire gate system. These weighting factors should be pre-determined by consensus among experienced hydropower engineers and plant O&M experts. Once they are determined for each part, they should be largely fixed from plant to plant for similar arrangements. Depending on the refining process during the demonstration and baseline assessments, the weighting factors for the parts/items associated with draft tube gates may have to be adjusted for some plants. In this case, the adjustment of weighting factors must be conducted by HAP core process development team. The range of absolute values of weighting factors will not affect the Condition Indicator of the gate system, which is the weighted summation of all scores assigned to the parts and five condition parameters.

Table 1: Typical Draft Tube Gates Condition Assessment & Scoring

Draft Tube Gates for Unit ____	Taxonomy ID	Physical Condition Score	Age Score	Installed Technology Score	Operating Restrictions Score	Maintenance Requirement Score	Data Quality Score	Weighting Factors for Parts
Draft Tube Gates	3.8.1							3.0
Gate Operating Equipment	3.8.2							2.0
Gate Seals	3.8.3							1.0
Gate Slots/Supports	3.8.4							1.0
Weighting Factors for Condition Parameters		2.0	1.0	1.0	1.0	1.5	Data Quality -->	0.00
							Condition Indicator -->	0.00

5.0 Rating Criteria

Physical Condition - Rating Criteria for Draft Tube Gates

Physical Condition of draft tube gates refers to those features that are observable or detected through measurement and testing. It includes gate seal deterioration, corrosion or damage of gate parts, presence of debris, damage or deterioration of gate slots and supporting piers, misalignment of gate slots due to concrete growth, etc. It is important that draft tube gates function properly since they are used in dewatering and the failure of a gate could have severe consequences. Therefore, draft tube gates should be carefully evaluated to ensure proper and safe functionality. The Best Practices for Draft Tube Gates can assist in evaluating the physical condition. For HAP site assessment, it is important to interview and discuss with plant personnel to help score the physical condition. The results of all related information are analyzed and applied to Chart 1.

Chart 1 Draft Tube Gates Physical Condition Rating Criteria		
Physical Condition Rating Scale		Physical Condition Score
Excellent	Limited or no deterioration or damage to gates; minimal leakage at gate seals; no deterioration, damage, or defects of gate seals; gate slots are in alignment and show not sign of movement; no deterioration or damage of concrete slots/supports; hoisting equipment is functioning properly and shows no sign of motor overload; hoisting equipments parts are in excellent condition. Gate system is functioning optimally and requires no repairs.	8 – 10
Good	Minor deterioration or damage to gates; moderate leakage at gate seals; minor deterioration, damage, or defects of gate seals; gate slots are in alignment and show signs of slight movement; minor deterioration or damage of concrete slots/supports; gates are functioning with minor binding during installation and removal; hoisting equipment is functioning and shows minimal signs of motor overload; hoisting equipments parts are in adequate condition. Gate system is functioning however minor repairs may be necessary.	5 – 7
Fair	Moderate deterioration or damage to gates; significant leakage at gate seals; moderate deterioration, damage, or defects of gate seals; gate slots misaligned and show sign of movement; moderate deterioration or damage of concrete slots/supports; hoisting equipment is functioning but shows moderate signs of motor overload; hoisting equipments parts are in fair condition. Gate system is functioning however moderate repairs may be necessary.	3 – 4
Poor	Severe deterioration or damage to gates; extensive leakage at gate seals; severe deterioration, damage, or defects of gate seals; gate slots are extremely misaligned; severe deterioration or damage of concrete slots/supports; hoisting equipment is functioning poorly with severe motor overload; hoisting equipments parts are in poor condition. Gate system no longer functions properly and replacement or extensive repairs are necessary.	0 – 2

<u>Age - Rating Criteria for Draft Tube Gates</u>

Age is an important factor when considering part upgrade as it can be an indication of performance degradation. As gate systems age, they become more susceptible to deterioration due prolonged exposure to moisture when in use and the elements when in storage. Not only does increased wear result in operational problems and loss of efficiency, it can also increase the risk of failure.

Age scoring is relatively more objective than other condition parameters. The detailed scoring criterion developed in Chart 2 allows the age score to be automatically generated in the HAP Database by the actual years of the installed part. The age scoring criteria for various parts are shown in Chart 2.

Chart 2 Age Rating Criteria for Draft Tube Gates

Age of Gate or Hoist Structural Parts and Supports	Age Score	Age of Seals	Age of Operating Equipment
<30 years	**8 - 10**	<10 years	<15 years
30-60 years	**5-7**	10-15 years	15-25 years
60-80 years	**3-4**	15-20 years	25-35 years
>80 years	**0-2**	>20 years	>35 years

<u>Installed Technology – Rating Criteria for Draft Tube Gates</u>

The Installed Technology indicates advancement in draft tube gate design, installation/construction techniques, hoisting techniques, corrosion protection, and gate seal configuration and material which may affect maintenance and reliability performance of the gates. Outdated technology may cause difficulties for supplying replacement parts or performing routine maintenance.

Scoring the Installed Technology requires historic knowledge of draft tube gate technology advancement and familiarity with industry standards and materials. For example, gate seal geometry and seal attachment have advanced in recent years. The use of rubber gate seals with a J-bulb shape have been more commonly used in the last 40 years. Recently, the use of stainless steel for gates and seal parts has been used with the advantage of providing corrosion protection.

The competence, professionalism, and reputation of the original suppliers could also impact the Installed Technology. As compared to highly reputable manufacturers with a good service record, the parts supplied or installed by unknown or disreputable companies would get lower scores. The Installed Technology scoring criteria for various parts are shown in Chart 3.

Chart 3 Draft Tube Gates Technology Rating Criteria	
Technology Levels of the Design and Construction	**Score for Installed Technology Level**
The technology has not been changed significantly since the part was installed; and the installed technology was supplied by brand name companies with a great reputation	**8 – 10**
The technology has been more or less advanced but no problem to supply the matching parts in next 5-10 years, or the technology change has little effect on the efficiency and reliability of power generation (but may reduce the cost of replacement). The installed technology was supplied by medium companies with good reputation.	**4 – 7**
The installed technology has been phased out, it is a problem to supply parts in reasonable order time, or the technology change has significantly improved the efficiency and reliability. The installed technology was supplied by small companies with bad reputation.	**0 – 3**

<u>Operating Restrictions - Rating Criteria for Draft Tube Gates</u>

The Operating Restrictions refers to the current limitations on the operating ranges. Draft tube gates are not part of normal plant operations and are primarily used only for plant maintenance and dewatering activities. Therefore, any restriction based on the condition of draft tube gates does not directly impact plant operations. Indirectly, issues with draft tube gates (i.e., gate binding or failure) can impact the length of unit shutdown during dewatering which consequently affects plant operations. Chart 4 describes the rating for operating restrictions.

Chart 4 Draft Tube Gates Operating Restrictions Rating Criteria	
Operating Restrictions or Off-Design Conditions	**Score for Operating Restrictions**
The design standard has no changes, and the original design has no constraints on the required operation.	**8 – 10**
Minimal restraints: Dewatering activities are affected by gate and hoisting equipment selection or design.	**5 – 7**
Moderate restraints: Dewatering activities are limited. The performance can be significantly improved with revised system design.	**3 – 4**
Severe limitations: The component does not meet the operational criteria, dewatering capabilities and reliability are significantly limited if it operates under current system design.	**0 – 2**

Maintenance Requirement – Rating Criteria for Draft Tube Gates

The amount of corrective maintenance that either has been or must be performed is an indication of the gate system condition. If draft tube gate or associated parts have required limited or no maintenance, then that is an indication that the system is in good condition. If a part has required extreme corrective maintenance, then the part is considered to be in poor condition.

Other factors to consider for maintenance scoring include:

- Maintenance needs are increasing with time or problems are re-occurring
- Previous failures or issues related to draft tube gates
- Failures or problems with draft tube gates of similar design and material

The results of the maintenance history (including routine maintenance and corrective maintenance) are analyzed and applied to Chart 5.

Chart 5 Draft Tube Gates Maintenance Requirement Rating Criteria	
Amounts of Corrective Maintenance	**Maintenance Requirement Score**
Minimum level (normal condition): A small amount of routine preventive maintenance is required. No corrective maintenance.	**9 – 10**
Low level: Small amounts of corrective maintenance (e.g., less than 3 staff days per component per year). Repairs that could be completed during a unit preventive maintenance outage that is scheduled on a periodic basis.	**7 – 8**
Moderate level: Some corrective maintenance that causes extensions of unit preventative maintenance outages.	**5 – 6**
Significant/Extensive level: Significant additional and corrective maintenance is required; forced outage occurs and outages are extended due to maintenance problems.	**3 – 4**
Severe level: Severe corrective maintenance that requires scheduled or forced outages. Repeated forced outages, frequent repairs, abnormal wear to components, and/or labor-intensive maintenance is required.	**0 – 2**

Data Quality – Rating Criteria for Draft Tube Gates

The Data Quality score reflects the quality of the inspection, test, and measurement results used to evaluate draft tube gates. The more current and complete the inspection, tests, and measurement results are, the higher the Data Quality scores. The frequency of normal testing is as recommended by the HAP assessment team in conjunction with industry standards.

Reasonable efforts should be made to perform visual inspections and data collection (measurements, tests, operation logs, maintenance records, design drawings, previous assessment reports, etc.). However, when data is unavailable to score a condition parameter properly, it may be assumed that the condition is "Good" or numerically equal to some mid-range number 3-7. Meanwhile, the Data Quality score is graded low to recognize the poor or missing data.

Qualified personnel should make a subjective determination of the Data Quality scores, considering as many factors as possible. The suggested criteria for scoring the Data Quality are developed in Chart 6.

Chart 6 Draft Tube Gates Data Quality Rating Criteria	
Data Availability, Integrity and Accuracy	**Data Quality Score**
High – The maintenance policies and procedures were followed by the plant and the routine inspections, tests, and measurements were performed within normal frequency in the plant. The required data and information are available to the assessment team through means of site visits, possible visual inspections, and interviews with experienced plant staff.	**8 – 10**
Medium – One or more of routine inspections, tests, and measurements were completed 6-24 months past the normal frequency, or small portion of required data, information and documents are not available to the assessment team.	**5 – 7**
Low – One or more of routine inspections, tests, and measurements were completed 24-36 months past the normal frequency, or some of results are not available.	**3 – 4**
Very Low – One or more of required inspections, tests and measurement were completed >36 months past the normal frequency, or significant portion of results are not available.	**0 – 2**

6.0 Condition and Data Quality Indicator

In Table1, the final condition score for flumes and open channels, i.e., the Condition Indicator, *CI*, can be calculated as follows:

$$CI = \frac{\sum_{K=1,M}^{J=1,5} S_C(K,J) \times F(K) \times F(J)}{\sum_{K=1,M}^{J=1,5} F(K) \times F(J)} \qquad (1)$$

The Data Quality Indicator, *DI*, will be the weighted summation of all Data Quality scores received for its associated parts:

$$DI = \frac{\sum_{K=1,M} S_D(K) \times F(K)}{\sum_{K=1,M} F(K)} \qquad (2)$$

Here M = the total number of parts associated with draft tube gates; K = the identification No. of parts (from 1 to M); J = the identification No. of condition parameters (from 1 to 5, respectively for physical condition, age,…); $S_C(K, J)$ = the condition score of a part for one of 5 condition parameters; $S_D(K)$ = the data quality score for a part; $F(J)$ = the weighting factor for a condition parameter; $F(K)$ = the weighting factor for a part.

The calculated Condition Indicator from equation (1) may be adjusted by the results of internal inspections and specific testing results that would be performed, since the specific testing would more directly reveal the condition of the draft tube gate system.

7.0 References

1. American Society of Engineers (ASCE, 2007), *Civil Works for Hydroelectric Facilities – Guidelines for Life Extension and Upgrade*, ASCE Hydropower Task Committee, 2007.

2. Electric Power Research Institute (EPRI, 1999), *Hydro Life Extension and Modernization Guide, Volume 1 – Overall Process*, TR-112350-V1, Palo Alto, CA: December 1999.

3. EPRI (2005), *Hydro Life Extension and Modernization Guide, Volume 6 – Civil and Other Plant Components*, TR-112350-V6, Palo Alto, CA: July 2005.

4. MWH (2010), *Final Report of Hydropower Modernization Initiative Asset Investment Planning Program*, Prepared for U.S. Army Corps of Engineers Northwest Division, Hydroelectric Design Center, October 21, 2010.

5. USACE (2001). *Major Rehabilitation Evaluation Report*, Center Hill Power Plant, prepared by U.S. Army Corps of Engineers, March 2001.

6. HAP Team (2011a). *HAP Best Practice Category of Hydropower Unit and Plant Efficiency Improvement*, prepared by Mesa, HPPi and ORNL.

7. HAP Team (2011b). *HAP Condition Assessment Manual*, prepared by ORNL, Mesa and HPPi.

8. TVA (2010). *Enterprise Asset Management (EAM) Asset database Modification and Unique Identification of Structures, Systems, and Components*.

9. March (2011). *"Best Practice" Guidelines for Hydro Performance Processes*, by Patrick March, Charles Almquist and Paul Wolff, Hydro Vision Conference, July 2011.

10. USACE (1985). Engineer Manual, No. 1110-2-1701. *Engineering and Design – HYDROPOWER*, US Army Corps of Engineers.

For overall questions
please contact:

Brennan T. Smith, Ph.D., P.E.
Water Power Program Manager
Oak Ridge National Laboratory
865-241-5160
smithbt@ornl.gov

or

Qin Fen (Katherine) Zhang, Ph. D., P.E.
Hydropower Engineer
Oak Ridge National Laboratory
865-576-2921
zhangq1@ornl.gov